SC/68C/HIM/08

Sub-committees/working group name: HIM

Cetacean Bycatch Risk in Gillnets and Trawls in Matang, Peninsular Malaysia

Sui Hyang Kuit & Louisa Shobhini Ponnampalam

Cetacean Bycatch Risk in Gillnets and Trawls in Matang, Peninsular Malaysia

Sui Hyang Kuit[1,2*], Louisa Shobhini Ponnampalam[1]
[1]*The MareCet Research Organization, Shah Alam, Selangor, Malaysia*
[2]*Institute of Biological Sciences, Faculty of Science, Universiti Malaya, Kuala Lumpur, Malaysia*
*Corresponding author: viviankuit@hotmail.com

ABSTRACT

Small cetaceans are particularly vulnerable to impacts from bycatch, yet baseline data on bycatch especially in developing countries are often mostly scarce. By integrating data from interviews and boat-based surveys conducted between 2013 and 2017, and using the Bycatch Risk Assessment (ByRA) toolkit, this study was to identify main bycatch gears and areas with highest bycatch risk of small cetaceans in Matang so as to guide planning for local bycatch mitigation strategies. A total of 198 respondents in 17 fishing villages in Matang were interviewed to assess fishers' perceptions, fishing effort, cetacean sightings and bycatch. The Indo-Pacific humpback dolphin was the most frequently reported cetacean species to be entangled by fishers. Gillnet, driftnet and trammel net were the main bycatch gears inshore that entangled humpback dolphins and Irrawaddy dolphins the most, whereas trawls were the more fatal bycatch gear offshore that entangled mostly Indo-Pacific finless porpoises. Kuala Sangga Besar and Kuala Larut were identified as areas with the highest cetacean bycatch risks. Bycatch mitigation trials such as the use of acoustic reflectors or pingers should be targeted on working with fishers using gillnets with mesh sizes of 1.5 to 4 inches that target threadfins, ariid catfishes, eel-catfishes, mullets, seabasses, and pomfrets off the two aforementioned areas for dolphin conservation. Exploration into the use of effective bycatch mitigation measures that do not greatly affect the fishers' catch would facilitate a wider adoption of those measures by more fishers to ensure better conservation success.

Keywords: *bycatch mitigation, bycatch risk assessment, conservation, entanglement, Indo-Pacific finless porpoise, Indo-Pacific humpback dolphin, Irrawaddy dolphin*

INTRODUCTION

Fisheries bycatch, or unintended mortality and injury in fishing gear, is regarded as one of the most serious conservation threats to many marine mammal populations worldwide (Nelms et al., 2021; Read, 2008; Reeves et al., 2013). Cetaceans are particularly vulnerable to the effects of mortality from bycatch, due to their distributions that often coincide with fishing activities, and the limited capacity for these populations to recover due to their late maturity, low reproductive rate and long life span (Brown et al., 2013). Additionally, baseline data on marine mammals, bycatch and fishing effort in developing countries are often fragmentary (Hines et al., 2015a; Komoroske & Lewison, 2015; Reeves et al., 2013). The lack of capacity and resources in developing countries in Southeast Asia often precludes assessments needed to highlight the most threatened populations and to inform conservation and management actions (Hines et al., 2015b).

Onboard observer programs are able to provide the highest quality of bycatch data (Lewison et al., 2004). However, the high costs of having trained observers to collect data aboard fishing vessels is not feasible especially for artisanal fisheries in developing countries, and hence interviews are recognized as a practical method to collect bycatch information for both artisanal and commercial fisheries when observer data were limited (Moore et al., 2010; Whitty et al., 2010). Furthermore in Malaysia, observer programmes for bycatch monitoring do not currently exist, and there are legal restrictions with regards to laypeople being onboard a commercial fishing vessel that is in operation. Rapid and low-cost interview surveys enable collection of information about the characteristics of artisanal fisheries and bycatch at a relatively low cost (Moore et al., 2010).

In the coastal waters of Matang, Peninsular Malaysia, at least three species of small cetaceans are recorded, namely Indo-Pacific humpback dolphins (*Sousa chinensis*), Irrawaddy dolphins (*Orcaella brevirostris*) and Indo-Pacific finless porpoises (*Neophocaena phocaenoides*). The Irrawaddy dolphin is listed as ‘Endangered’ (Minton et al., 2017), whereas the Indo-Pacific humpback dolphin (hereafter referred to as humpback dolphin) and Indo-Pacific finless porpoise (hereafter referred to as finless porpoise) are listed as ‘Vulnerable’ (Jefferson et al., 2017; Wang & Reeves, 2017) on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Since 2019, Matang’s coastal waters spanning 2386 km^2 have been designated as the Matang Mangroves and Coastal Waters Important Marine Mammal Area (IMMA) by the IUCN.

In Matang, Indo-Pacific humpback dolphins are patchily distributed mainly in the shallow estuarine waters (<10 m deep and <5 km from river mouths), whereas Irrawaddy dolphins are more widely distributed in farther coastal waters (<15 m deep and <15 km from river mouths), and Indo-Pacific finless porpoises are mostly found farthest from the shore in coastal waters (10–25 m deep and >15 km from river mouths) (Kuit et al., 2019a). The inshore resident humpback dolphins were found to display high site fidelity and frequently moved between the five main estuaries in Matang to utilize the productive and sheltered estuaries as feeding and nursery grounds (Kuit et al., 2019b). The annual abundance of humpback dolphins was estimated to fluctuate between 171 (mark-recapture CV = 10.1%; 95% CI = 148-208) in 2014-2015 and 81 (mark-recapture CV = 9.8%; 95% CI = 67-98) in 2015-2016 (Kuit et al., *in review*). Irrawaddy dolphin abundance was estimated to be 763 individuals (line-transect CV = 13.3%; 95% CI = 588-990) and finless porpoises at 600 individuals (line-transect CV = 27.1%, 95% CI = 354-1016), with average density of less than one individual per square kilometer (Kuit et al., *in review*).

The extensive stretch of mangrove-fringed brackish riverine waterways and coastline of Matang are important nursery and feeding grounds for cetaceans, marine fish and invertebrates (Chong et al., 2012; Kuit et al., 2019a; Tanaka et al., 2011). The coastal waters of Matang in Perak state are one of Malaysia’s most productive fishery grounds, with annual marine fishery landings of more than 300,000 tonnes, which is approximately one-fifth of total marine fish landings in Malaysia (Department of Fisheries Malaysia, 2016). The combined fish and prawn landings in Matang in 2011 was estimated to be 151,382 tonnes, with a total economic value of RM981.47 million (Ariffin & Nik Mohd Shah, 2013). A total of 163 species of fish, 37 species of prawns and shrimps, and 45 species of crabs were recorded in Matang, of which 112 species of fish (69%), 27 species of prawns (73%) and 6 species of crabs (13%) are commercially exploited (Ariffin & Nik Mohd Shah, 2013; Ashton, 1999; Chong, 2005; Chong et al., 1994, 2012; Hanamura et al., 2012; Hayase & Muhd Fadzil, 1999; Low et al., 1999; Sasekumar et al., 1994; Tanaka et al., 2011; Then, 2008). Traditional fishing methods in Matang include gillnet, trammel net, bag net, push net, hook-and-line, longlines, and crab trap that are mostly operated within the mangrove channels and within 8 km from shore. Commercial fishing gears operating in Matang include trawl nets and purse seine nets (Ariffin & Nik Mohd Shah, 2013). The main traditional fishing gear used in Matang is the gillnet, whereas the main commercial gear is the trawl net.

This study was undertaken to identify the fishing gear types and areas with highest bycatch risk of small cetaceans in Matang for bycatch mitigation efforts. By integrating data from interviews with local fishers and boat-based surveys, the outputs from the Bycatch Risk Assessment (ByRA) toolkit can identify particular species, fishing gears and locations with high interaction rates (Hines et al., 2020; Verutes et al., 2020) and can be used to guide fisheries management and focus bycatch mitigation strategies.

METHODOLOGY

Study site

Matang is located in Perak state, on the northwestern coast of Peninsular Malaysia. The size of the study site is approximately 1152 km^2 and stretches 56 km along the coastline from Kuala Gula in the north to Kuala Jarum Mas in the south, and extends up to 24 km from the coastline (Figure 1). The study site is divided into four subregions, namely North Coastal, North Estuarine, South Coastal, and South Estuarine. Most of the fishing activities conducted in the study site are carried out by fishers from the fishing villages along the 56 km coast, and were chosen as the targets for interviews with fishers in the present study.

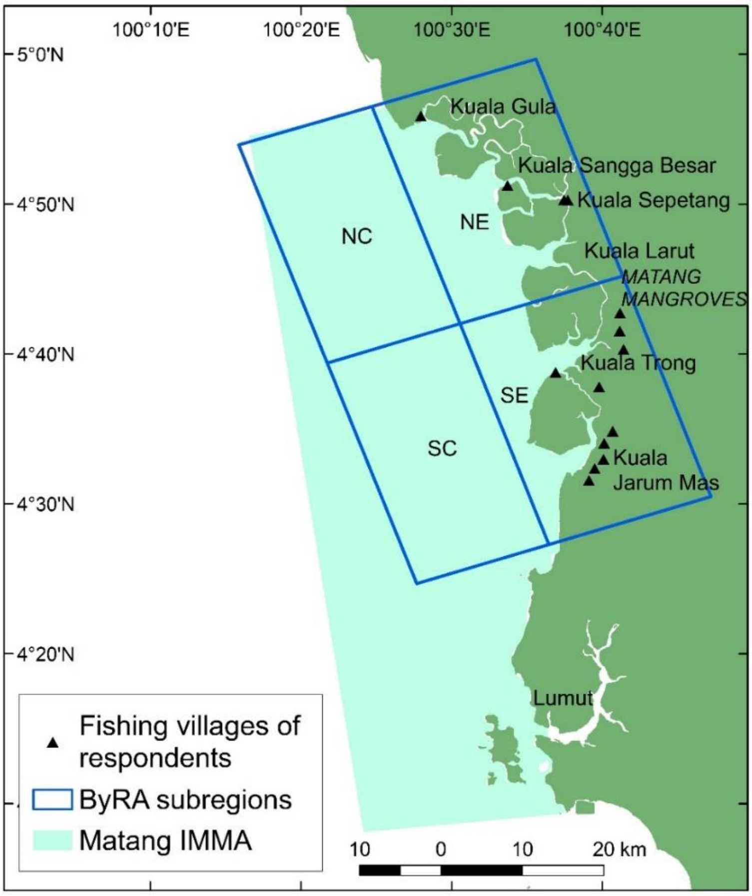

Figure 1: The location of fishing villages of respondents interviewed in this study, the Bycatch Risk Assessment (ByRA) subregions in the survey area, and the boundaries of the Matang Mangroves and Coastal Waters Important Marine Mammal Area (IMMA). Subregions: NC: North Coastal; NE: North Estuarine; SC: South Coastal; SE: South Estuarine

Data collection

Interview surveys

Interview surveys with local fishers in fishing villages along Matang's coast were conducted between February 2014 and February 2017. The interview questionnaire was adapted from Pilcher & Kwan (2012), and covered a wide range of topics from the fishers' background, fishing as livelihood, fisheries trends, fishing vessel used, frequency of fishing, fishing areas, fishing gears used, target catch, previous cetacean sightings and strandings, local ecological knowledge and perception about cetaceans, and occurrences of cetacean bycatch. Pilot studies were carried out to improve the flow and minimize possible misunderstandings of the questions, and were practised with a social scientist.

Fishing villages were visited to conduct face-to-face interviews with local fishers who fish within the study area. Efforts were made to conduct the interviews by sampling fishers who used the major fishing gear types in each fishing village. Each respondent was interviewed individually in either the Malay language or Chinese dialect (e.g., Mandarin, Cantonese or Hokkien), according to the preference of the respondent. A custom-designed species identification guide was shown to help respondents identify the three cetacean species. Respondents could provide more than one response for open-ended questions. At the end of each interview, the reliability of the respondents was separately rated for their openness in answering bycatch questions, their level of interest, their level of certainty in numerical questions, and their ability to discriminate between the cetacean species. Responses with the lowest scores were excluded from analyses.

Boat-based surveys

Eleven 10-day line-transect surveys were conducted almost bimonthly between November 2013 and July 2016, except for months with unfavourable weather (i.e., May & November 2014, January & November 2015, March & May 2016). A GPS waypoint was marked using a handheld GPS (Garmin GPSMAP 78s; Garmin, Olathe, KS) when the research vessel was near a cetacean group. Information from each sighting was recorded into a sighting recording form, which included data such as date, time, GPS location, species, and best estimate of group size. The type and quantity of human activities, particularly fishing activities (e.g., type and number of fishing gears) that were present within a radius of 500 m from the research vessel were also recorded.

Data processing and analysis

Interview surveys

The answers of questionnaires were entered into an Excel database. The responses of interviewed local fishers in Matang were analyzed quantitatively to understand their general perception of cetaceans and to identify the prevalence of bycatch in Matang. Responses to open-ended questions were coded to standardized categories and numerical answers were sorted into three to four bins, similar to Whitty (2014). Since respondents could provide more than one answer per question and some respondents did not provide an answer for certain questions, the percentages for the number of answers in each answer category were calculated by using the total number of answers per question, similar to Kreb et al. (2020). Fishing areas of respondents by gear type and cetacean bycatch locations were plotted using the program ARCMAP 10.3.1. The two main fishing gears that were identified from interviews as the bycatch gears that were most involved in bycatch of small cetaceans in Matang were noted as 'stressors' in the Bycatch Risk Assessment (ByRA) analysis (more information below).

Bycatch risk assessment (ByRA)

The Bycatch Risk Assessment (ByRA) toolkit in the program InVEST 3.6.0 was used to evaluate the spatial risk of bycatch to small cetaceans. The risk of fisheries bycatch was calculated in the ByRA tool based on the likelihood of exposure (interactions between animals and the fishery) and the consequence to the species (Verutes et al., 2020). Information on the two main bycatch gears (stressors) that were identified from interview surveys were organized into two distinct categories: (1) nets (which included gillnets, driftnets and trammel nets) and (2) trawls (which included fish trawl nets and shrimp trawl nets). Positions of cetacean sightings and fishing activities observed during boat surveys were plotted and overlaid on a map using the program ARCMAP 10.3.1. Kernel density estimation (KDE) was used to map the intensity of fishing activity and cetacean sightings needed to generate the corresponding shapefiles for the ByRA. Polygon kernel density shapefiles of the three cetacean species, and the two stressors in Matang were then reclassified into three rating scores using Jenks natural breaks for the rating field (3 for high, 2 for medium, and 1 for low). For the management shapefiles, the exposure scores were scored as “1” if management strategies were identified and implemented, “2” if management strategies were identified but not implemented, and “3” for areas where no management strategies were identified (Verutes et al., 2020). For the subregion shapefiles, the area of interest in the study area was divided into four subregions following the survey strata (i.e., North Coastal, North Estuarine, South Coastal, and South Estuarine). The Habitat Risk Assessment Preprocessor in InVEST 3.6.0 was run, and the ratings, data quality and weight for the species and stressors were scored as guided by field observations, results of interview with local fishers and literature review, following the criteria defined in Verutes et al. (2020).

The ByRA Pre-processor was then run in the software QGIS 3.8.0, followed by the Habitat Risk Assessment in InVEST 3.6.0 to generate the bycatch risk maps. To quantify bycatch risk in ByRA, exposure scores are calculated based on the overlap between species distribution and the extent of human activity in space and time, whereas consequence scores are calculated based on assessment of how a population will respond to an impact (Hines et al., 2020; Verutes et al., 2020). The stoplight approach as per Hines et al. (2020) was used to characterize levels of uncertainty and to visualize data quality for ByRA data categories in Matang. Data were characterized as either green (data with high certainty from robust methodologies), yellow (data with medium certainty that were collected opportunistically) or red (data with low certainty with insufficient data or effort) (Hines et al., 2020).

RESULTS

Fishing gears and areas

A total of 198 respondents were interviewed over 21 days between February 2014 and February 2017 in 17 fishing villages in Matang. The common gears used by respondents were gillnet, driftnet and trammel net (25%, n = 58), followed by push net (24%, n = 56), trawl net (21%, n = 48), crab trap (14%, n = 32), bag net (8%, n = 19), cockle collection (4%, n = 9), hook and line (3%, n = 6), longline (0.9%, n = 2) and purse seine (0.4%, n = 1). Most of the fishers using gillnets, driftnets and trammel nets (96%, n = 43) tended their gears. When asked about soak times of their gears, gillnets were mostly left up to 4 hours (31%, n = 11), followed by up to 2 hours (26%, n = 9). Trammel nets were mostly left up to 1 hour (50%, n = 3). Bag nets were mostly left in the water for up to 4 hours (65%, n = 11). Push nets were mostly operated up to 2 hours (27.3%, n = 3). Crab traps were mostly left soaking up to 1 hour (41%, n = 7). Trawl nets were mostly trawled up to 2 hours (52%, n = 12), followed by up to 4 hours (39%, n = 9). The fishing areas of respondents by gear type are presented in Figure 2.

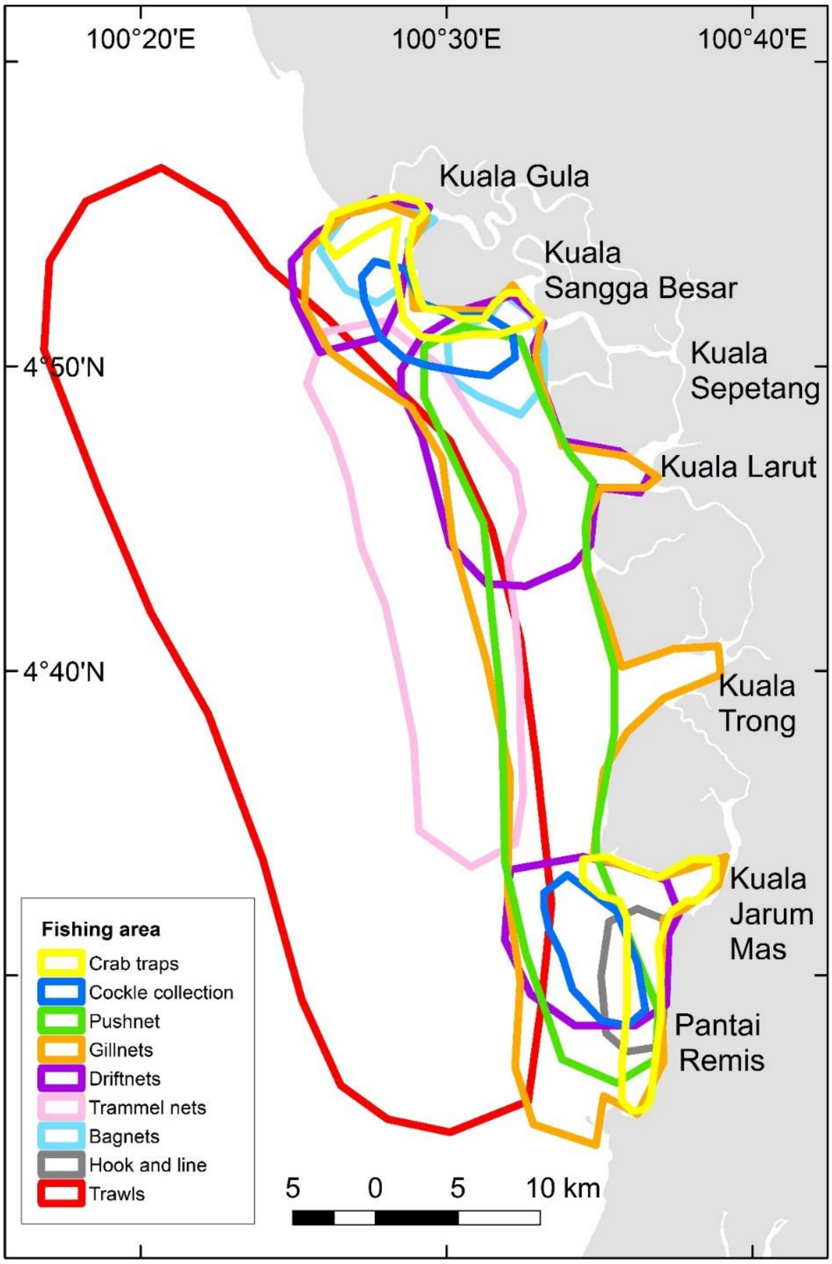

Figure 2: Fishing areas of respondents by gear type

<u>Cetacean sightings</u>

All 198 respondents (100%) had sighted cetaceans in Matang. The majority of the respondents (60%, n = 119) had only sighted humpback dolphins, whereas 20% (n = 40) had sighted both humpback dolphins and Irrawaddy dolphins (Table 1). Only 4% of the respondents (n = 7) had sighted all three species of cetaceans (humpback dolphins, Irrawaddy dolphins and finless porpoises) that were found in Matang.

Table 1: Species of cetaceans seen by respondents in Matang

Cetacean species seen in Matang		
N	*198*	
Seen humpback dolphin only	119	60.1%
Seen humpback dolphin and Irrawaddy dolphin	40	20.2%
Seen humpback dolphin and finless porpoise	19	9.6%
Seen humpback dolphin, Irrawaddy dolphin and finless porpoise	8	4.0%
Seen Irrawaddy dolphin only	7	3.6%
Seen finless porpoise only	3	1.5%
Seen Irrawaddy dolphin and finless porpoise	2	1.0%

When asked about their perceived trend in cetacean abundances, 46% (n = 91) of the respondents felt that the abundance in Matang had decreased, 21% (n = 42) felt that the abundance was the same, 20% (n = 39) felt that the cetacean abundance had increased, and 13% (n = 26) said that they did not know. When asked whether they like cetaceans, most of them responded positively (71%, n = 140), 21% (n = 41) were neutral, and 8% (n = 15) did not like cetaceans. Common reasons for liking cetaceans were that the animals were enjoyable to be observed at sea (60%, n = 73) and that cetaceans are playful animals that would interact with their fishing boats (12%, n = 15). The main reasons for disliking cetaceans were that the animals compete with fishermen for fish (56%, n = 5) and that cetaceans damage their nets (44%, n = 4).

When asked if they felt that cetaceans are important, most respondents (69%, n = 137) felt that cetaceans are important, 22% (n = 44) were neutral and 9% (n = 17) felt that cetaceans were not important. Positive perceptions about cetacean importance were mainly because cetaceans are enjoyable to observe (38.3%, n = 64), are a potential tourist attraction (28%, n = 46), are part of the ecosystem (14%, n = 23) and are indicator of fish presence (9%, n = 15). Most of the respondents (72%, n = 142) felt that there is potential for dolphin-watching tourism in Matang. However, respondents who felt that cetaceans are unimportant viewed cetaceans as competition with fishermen for fish (59%, n = 10) and having no economic value (35%, n = 6). When asked whether it is illegal to kill cetaceans intentionally, 81% (n = 158) answered "yes", whereas 22% (n = 43) answered "no" and the remaining 7% (n = 13) said they did not know. However, when subsequently asked if it is illegal to kill cetaceans unintentionally (e.g., bycatch), the majority of respondents (77%, n = 149) felt that it was not illegal, whereas 12% (n = 24) still felt that it was illegal even though the catch was accidental.

Fisheries interactions with cetaceans

Regarding perceptions about the current trend in cetacean bycatch in Matang compared to when the respondents started fishing, most of them (60%, n = 108) said they did not know or never had bycatch, and 23% (n = 41) thought it had decreased. Eighteen respondents (10%) thought that the bycatch rate was the same and 8% (n = 14) thought that it had increased. When asked about the reason for perceived decrease in cetacean bycatch, 73% (n = 8) of the respondents said because there were less cetaceans now, 18% (n = 2) said because cetaceans are clever or smart animals and would not be caught easily, and 9% (n = 1) said because the present day's fishing technology is better. When asked about the reason for perceived increase in cetacean bycatch, most of the respondents (75%, n = 3) said because of the increased fishing effort or increase in size of nets deployed.

When asked whether cetaceans had ever damaged their fishing gears, 11% (n = 22) of the respondents reported that their gears had been damaged by cetaceans. The majority of the respondents with fishing gear damaged by cetaceans were using gillnets (55%, n = 12), followed by trawl nets (27%, n = 6), trammel nets (9%, n = 2) and driftnets (9%, n = 2) (Table 2). Most of these respondents' target fish catches were threadfins (Family Polynemidae), ariid catfishes (Family Ariidae), eel-catfishes (Family Plotosidae), mullets (Family Mugilidae), seabasses (Family Latidae), and pomfrets (Family Stromateidae).

When asked whether cetaceans were previously caught in their gears, 28 respondents (14%) said that they had had bycatch (Table 2). Of these 28 respondents with bycatch, most of them were using gillnets (39%, n = 11), followed by trawl nets (36%, n = 10), driftnets (11%, n = 3), trammel nets (11%, n = 3) and bag nets (4%, n = 1) (Table 2). Entanglements in gillnet, driftnet and trammel net encompassed 61% of the cetacean bycatch. When asked if they had bycatch in the last calendar year, most of them reported that they did not have bycatch (58%, n = 15), but nine respondents (35%) reported that they had had between one to two bycatch incidents, and two respondents (8%) reported that they had had three or more bycatch incidents. The total cetacean bycatch incidents of these 11 respondents in the last calendar year was up to 22 animals. Throughout their lifetime (from when they started fishing to the interview date), most of the respondents (77%, n = 20) reported that they had one to two bycatch incidents, and 12% (n = 3) had more than 10 bycatch incidents. One respondent (n = 4%) said that he had about 100 bycatch of finless porpoises in pair trawls throughout his 40 years of fishing. Respondents using gillnets, driftnets and trammel nets that had bycatch mostly had mesh sizes of 1.5 to 4 inches and their target catches were mostly ariid catfishes, eel-catfishes, threadfins, mullets, seabasses, pomfrets, mackerels, and shrimps/prawns.

Table 2: Percentage of respondents who reported about cetaceans damaging fishing gear and cetaceans caught in fishing gear

Cetacean ever damaged your gear?		*N*	193	
	No		171	88.6%
	Yes		22	11.4%
Fishing gears damaged by cetaceans	Gillnet		12	54.5%
	Trawl net		6	27.3%
	Driftnet		2	9.1%
	Trammel net		2	9.1%
Cetacean ever caught in your gear?		*N*	198	
	No		170	85.9%
	Yes		28	14.1%
Fishing gears with cetacean bycatch				
	Gillnet		11	39.3%
	Trawl net		10	35.7%
	Driftnet		3	10.7%
	Trammel net		3	10.7%
	Bag nets		1	3.6%

When asked about their actions taken when bycatch occurs (there could be more than one response per respondent), 57% (n = 172) of the responses were that they would release the animal if it was still alive and 36% (n = 108) would discard if the animal was dead. Eight responses (3%) were that they would report the incident to the Department of Fisheries Malaysia, Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN), or Taiping Zoo. Four respondents (1%) said that they would eat the bycaught animal. Three respondents (1%) said they would bury the animal if dead and three respondents (1%) said they would bring the carcass back to show to other villagers. Two respondents (0.7%) would kill the animal if it was entangled in their gears, and one respondent (0.3%) said that he would sell it.

When asked to provide further details of the bycatch event that they could remember, only 19 respondents (67%) provided further details (Table 3). Of these 19 respondents, 10 fishers used gillnets, four fishers used trawl nets, three fishers used driftnets, one fisher used trammel net and one fisher used bag nets (Table 3). The most commonly bycaught cetacean species was humpback dolphins (n = 11), followed by Irrawaddy dolphins (n = 3), and finless porpoises (n = 2). The most common number of animals entangled at any given time was one individual, followed by three individuals (Table 3). When asked about the fate of the bycatch incidents, all four respondents that had bycatch in trawl nets reported that the cetaceans caught died (100%, n = 4). Fifty percent of the entanglements in gillnets, driftnets and trammel nets (n = 7) were reported to be dead, whereas the remaining 50% (n = 7) of the entanglements were reported to be alive and released (Table 3). Eight out of 19 respondents reported that the locations of their cetacean bycatch in gillnets, driftnets, trammel nets and bag nets were in Kuala Gula, Kuala Larut and Kuala Jarum Mas (Table 3; see Figure 1). Locations of cetacean entanglements in trawl nets could not be recalled by the respondents. When asked if these bycatch were reported, all of these 19 cetacean bycatch cases were not reported to the authorities.

Table 3: Further information about bycatch cases encountered by fishers in Matang

No.	Species	Number of animal(s)	Size of the animal(s)	Year	Fate	Fishing gear	Location
1	Humpback dolphin	3	Small	2004	Dead	Trawl net	N/A
2	Finless porpoise	1	Large	2012	Dead	Trawl net	N/A
3	N/A	1	Small	2012	Dead	Trawl net	N/A
4	Finless porpoise	1	Small	N/A	Dead	Trawl net	N/A
5	Humpback dolphin	1	Large	2002	Alive	Gillnet	Kuala Jarum Mas
6	Irrawaddy dolphin	1	Medium	2005	Dead	Gillnet	N/A
7	Humpback dolphin	1	Large	2007	Alive	Gillnet	Off Kuala Gula
8	Irrawaddy dolphin	1	Large	2008	Alive	Gillnet	N/A
9	Humpback dolphin	1	Small	2012	Dead	Gillnet	Off Kuala Larut
10	Humpback dolphin	1	Large	2016	Dead	Gillnet	N/A
11	Humpback dolphin	3	Small	N/A	Alive	Gillnet	N/A
12	Humpback dolphin	1	Large	N/A	Alive	Gillnet	N/A
13	Humpback dolphin	1	Large	N/A	Dead	Gillnet	5nm off Kuala Larut
14	Humpback dolphin	1	Large	N/A	Dead	Gillnet	N/A
15	Humpback dolphin	1	Large	1970s	Alive	Driftnet	Kuala Gula
16	Humpback dolphin	1	Large	2009	Alive	Driftnet	Kuala Jarum Mas
17	Humpback dolphin	1	Small	2013	Dead	Driftnet	N/A
18	Irrawaddy dolphin	1	Large	1970s	Dead	Trammel net	Off Kuala Gula
19	Humpback dolphin	1	Large	2007	Alive	Bag net	Kuala Gula

Bycatch risk assessment (ByRA)

The ByRA outputs revealed that a large proportion of the survey area in Matang posed medium to high bycatch risk to the small cetaceans there (Figure 3). Among the four research subregions in Matang, medium bycatch risk of humpback dolphins was patchily distributed throughout the four subregions, and was particularly high off the estuaries of Kuala Sangga Besar and Kuala Larut, and inside the riverine waterways (Figure 3a). These estuaries were areas where high density of gillnets, driftnets, trammel nets posed bycatch risk to humpback dolphins. Medium to high bycatch risk to Irrawaddy dolphins were widely distributed across the four subregions, with trawls posing highest bycatch risk in large proportions of the South Coastal and North Coastal subregions (Figure 3b). As for finless porpoises, trawls posed medium to high bycatch risk and were widely distributed in the North Coastal and South Coastal subregions (Figure 3c).

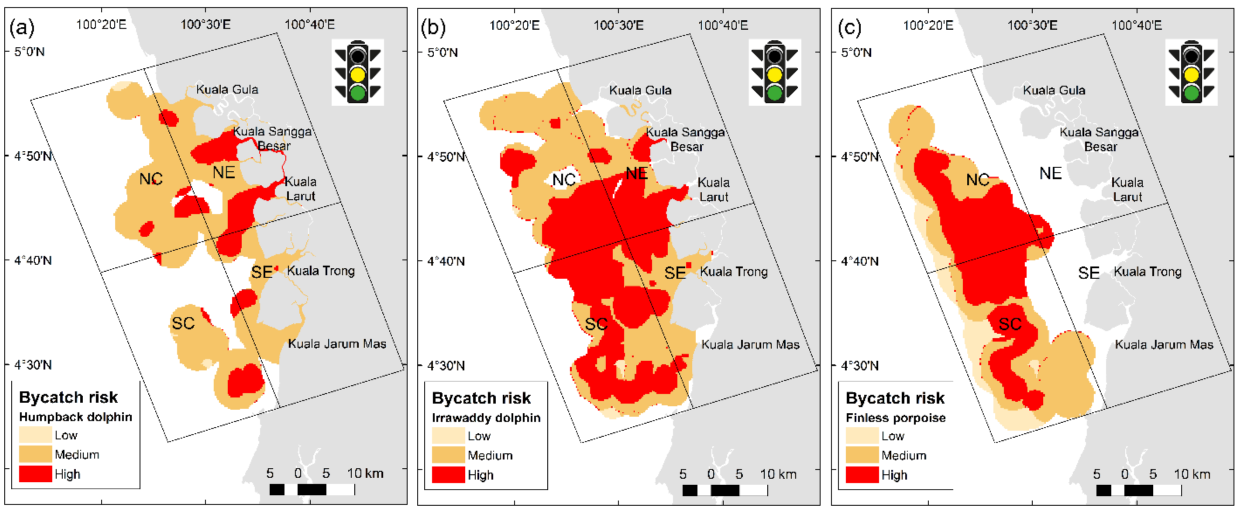

Figure 3: Estimated bycatch risk for (a) humpback dolphins, (b) Irrawaddy dolphins and (c) finless porpoises in Matang. Darker red indicates higher bycatch risk. Stoplight colours indicate level of uncertainty of ByRA data inputs. ByRA subregions: NC: North Coastal; NE: North Estuarine; SC: South Coastal; SE: South Estuarine

The spatial data layers used in the ByRA analysis were from sightings of dolphins and fishing activities collected during line transect surveys between 2013 and 2016. Two stressors were chosen based on the number of fishing gear records and the reported main bycatch gears from interview data (Table 4). The level of uncertainty for each ByRA data category are shown in Table 5. Data in Matang showed a combination of green (high certainty) and yellow (medium certainty). For humpback dolphins and Irrawaddy dolphins, gillnets, driftnets and trammel nets had the highest exposure scores, whereas trawls had the highest consequence scores (Figure 4a,b). For finless porpoises, trawls had the highest exposure and consequence scores in all four subregions (Figure 4c).

Table 4: Summary of spatial data layers (species and stressors) used in bycatch risk assessment (ByRA)

Spatial data layer	Type	n
Species (sightings)	Humpback dolphin	124
	Irrawaddy dolphin	254
	Finless porpoises	102
Stressors (fishing gear records)	Nets	199
	Trawls	303

Table 5: Characterization of uncertainty for bycatch risk assessment (ByRA) data category in Matang. Green: high certainty; Yellow: medium certainty

ByRA data category	Data source and type collected in Matang
Dolphin distribution	Systematic line transect boat and photo-ID surveys
Fishing occurrence	Collected during line transect surveys and from interviews
Bycatch data	Presence/absence of bycatch from interviews

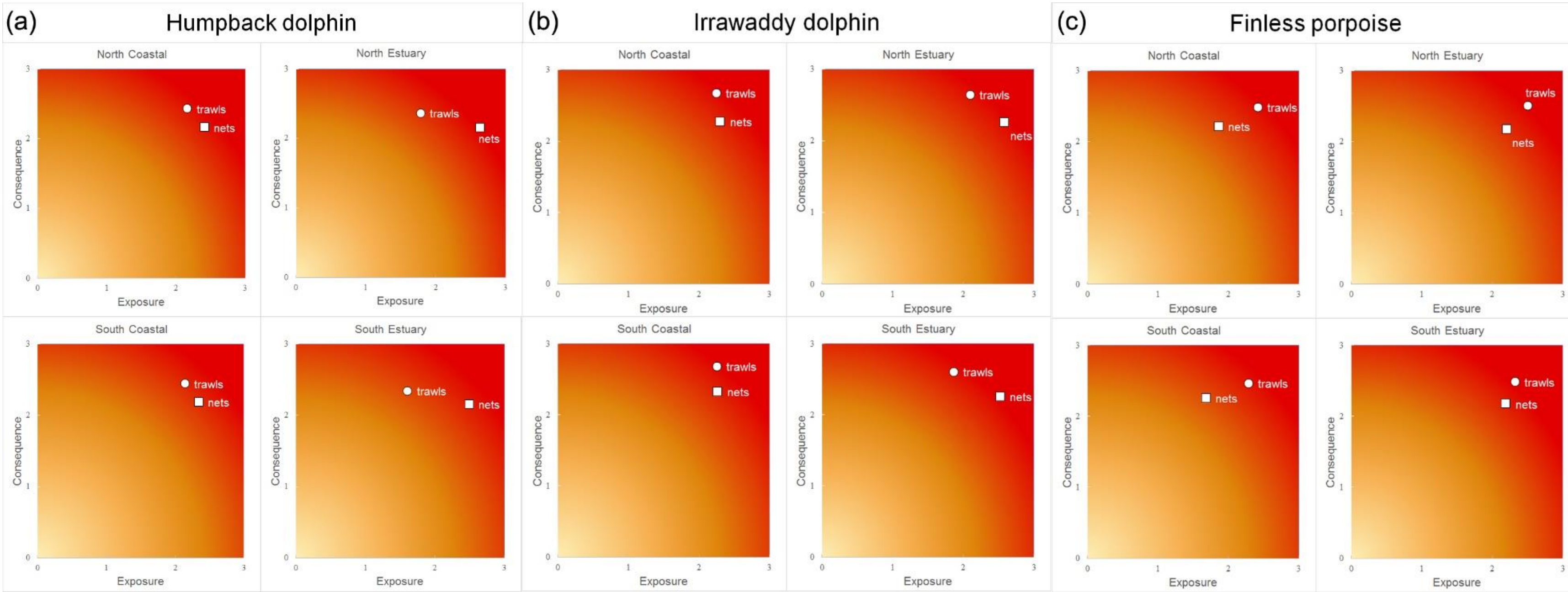

Figure 4: Bycatch risk plots showing consequence and exposure scores of nets (i.e., gillnets, driftnets and trammel nets) and trawls to (a) humpback dolphins, (b) Irrawaddy dolphins and (c) finless porpoises in four subregions. Darker red region (higher exposure and consequence) indicates higher risk of bycatch

DISCUSSION

All respondents had sighted cetaceans in Matang but only 4% of the respondents had sighted all three species of cetaceans in Matang. Humpback dolphins were more frequently sighted by fishers, probably due to their inshore distribution and were relatively more surface active compared to the more elusive Irrawaddy dolphins and finless porpoises. Adult humpback dolphins also have light pink pigmentation and bigger dorsal fins, hence are easier to be spotted than Irrawaddy dolphins and finless porpoises. Fishers who deploy bag nets or push nets mostly remained inshore and were less likely to encounter finless porpoises and Irrawaddy dolphins that were distributed much farther from the coast (Kuit et al., 2019a). Finless porpoises were least sighted by fishers in Matang, probably due to their evasiveness, offshore distribution, and smaller group sizes. It was found during the interviews that the slight physical differences between Irrawaddy dolphins and finless porpoises (i.e., absence of dorsal fin in finless porpoise, smaller in size and darker), both of which have rounded heads that lack a rostrum, were not easily distinguishable by fishers during brief sightings, similar to Jefferson et al. (1993). This highlights the challenge of using interviews to collect information about cetacean species that are physically similar and are elusive, evasive and distributed farther offshore.

By integrating currently available data from interviews with local fishers and boat-based surveys, interview results can help to identify main bycatch gears and cetacean species of concern, while ByRA outputs can identify particular areas with high cetacean-fisheries interaction rates that can be prioritized for design of bycatch mitigation trials (Hines et al., 2020; Verutes et al., 2020). Based on interviews results, gillnet, driftnet and trammel net are the main bycatch gear inshore that entangle humpback dolphins and Irrawaddy dolphins, whereas trawls are the main bycatch gear offshore that entangle finless porpoises.

The identified areas of concern for bycatch (Figure 3) were based on ByRA outputs on the intensity of operating nets (i.e., gillnets, driftnets and trammel nets) that were associated with greater exposure, and trawl nets that were associated with greater consequences for mortality (Figure 4). While new fishing zoning effective from June 2014 regulated that trawlers in Perak can only operate beyond eight nautical miles from shore (Department of Fisheries Malaysia, 2015), there were single and paired trawlers that were observed to be operating less than eight nautical miles from shore, causing exposure and thus bycatch risk of inshore dolphins to trawling activity (Kuit, pers. obs.). The exposure of dolphins to bycatch is also increased due to lack of cetacean bycatch management strategies during the survey period.

Entanglements in gillnets and trammel nets is a serious threat to populations of humpback dolphins, Irrawaddy dolphins and finless porpoises in Asia (Reeves et al., 2013), and is regarded as the principal cause of declines to many coastal and riverine small cetaceans with conservation status that has significantly worsened (Brownell et al., 2019). Similar to bycatch risk assessment in three other sites in Southeast Asia, the bycatch risk of Irrawaddy dolphins is highest from gillnets (Hines et al., 2020), reiterating the severity of the said gear to the species and other small cetaceans, even in Matang. The humpback dolphin is the main species of concern for bycatch in gillnets, given that they are most frequently reported by respondents to be entangled in Matang. The concern comes especially with the species' low abundance of fewer than 100 inshore resident individuals that frequently utilize the estuaries as feeding and nursery grounds. Bycatch mitigation trials should focus on working with gillnetters that had entanglements or had their gears damaged by cetaceans in the past, particularly with fishers who use gillnets with mesh sizes of 1.5 to 4 inches that target threadfins, ariid catfishes, eel-catfishes, mullets, seabasses, and pomfrets off Kuala Sangga Besar and Kuala Larut (Figure 3). These fish species are likely the prey species of humpback dolphins in Matang (Kuit et al., 2015), and hence these gillnetters are likely to have higher fisheries interactions with humpback dolphins that are more frequently encountered inshore and are reported to depredate gillnets.

While most gillnetters reported that they tended their gillnets that are mostly left to soak between 2 to 4 hours, gillnetters usually would deploy several gillnets in the area before returning to haul in their nets in the sequence of deployment, and they might not have noticed that a cetacean entanglement had occurred in a particular gillnet if they were occupied with deploying or hauling in other nets at the same time. About half of the entanglements were reported to be dead, with the remaining half reported to be alive and released. Cetaceans caught in nets set near the surface are able to surface to breathe for some time despite their entanglements until they become too weakened (Soulsbury et al., 2008). However, the reliability of high claims of live releases could not be assessed, similar to Pilcher et al. (2017). There may be possible bias that the entanglements found alive in gillnets may have been over-reported by fishers, as fishers might have chosen mostly to report the entanglements that were alive when released and did not disclose the ones that were found to be dead. One fisher had reported more than 10 bycatch of humpback dolphins in gillnets targeting Sagor catfish (*Hexanematichthys sagor*) in his 47 years of fishing. He admitted to hitting some of the entangled humpback dolphins on their rostrum to kill them, for fear of being bitten. According to the fisher, he had only released one individual, which was entangled on the fluke. Bycaught cetaceans that were released alive or escaped may suffer a variety of injuries that are likely to contribute to pre-mortem stress and affect subsequent long-term survival (Soulsbury et al., 2008).

According to Pilcher et al. (2017), a perceived decreasing trend of cetaceans being bycaught in fishing gears could indicate either a decrease in entanglements (positive) or a decrease in cetacean abundance (negative). Most of the respondents in Matang felt that the cetacean bycatch rate in Matang has reduced, due to lesser cetaceans in present day. This implies that the number of bycaught cetaceans may be higher in the past, and as more cetaceans died from entanglements, the decreased abundance of cetaceans in Matang has thus led to lower probability of entanglement presently. However, there are there no comprehensive studies on cetacean abundance estimates and bycatch in Matang from the past for comparison. Similarly within the wider Southeast Asia region, abundance estimates and quantification of bycatch rates are scarce, especially the latter.

Entanglements in trawl nets posed high bycatch risk to finless porpoises in Matang. In particular, based on interview data, pair trawls (whereby two trawlers maintain a certain distance apart to have a wide mouth opening of the trawl net) appeared to have caught many finless porpoises in Matang, at least in the past. Entanglements in trawl nets appeared to be mostly fatal, as the soak times of trawl nets are usually between 2 to 3 hours, which is much longer than the maximum dive time of these small cetaceans (Parra & Jefferson, 2018; Stacey & Leatherwood, 1997), and the animal trapped in trawl nets would have likely died from asphyxiation. Entanglements in a trawl net moving midwater or on the bottom and behind a trawler would be almost impossible to be detected and released, unless the trawl net was hauled up shortly after a cetacean was entangled. Destructive fishing practices such as trawling should also be phased out, or ideally banned, at least in areas of high cetacean bycatch risk. Fishing boat-related mortality of dolphins were found to be reduced in the subsequent years following trawling bans in Hong Kong (Klein, 2017). As pointed out in Slooten et al. (2021), it is essential to act early on marine mammal conservation issues, or longer delays would require more expensive and extreme measures. While the progress towards effective conservation measures may be slow, the trawling zone should be patrolled regularly by enforcement agencies to ensure that the pair trawls are not operating illegally in the coastal waters of Matang. Trials on the effectiveness of bycatch mitigation measures such as pingers and exclusion devices on trawl nets in Matang should be considered for the conservation of finless porpoises. At present, only shrimp trawlers in four states in the country are legally required to have turtle excluder devices (TEDs) installed on their trawl nets since 2017 due to import regulations with the United States of America (Khalid et al., 2021; Pilcher, 2016).

Some gillnet and trawl fishers that were interviewed either did not like cetaceans or were neutral about them. Similar to observations by Whitty (2014), these fishers also perceived cetaceans as competitors for fish resources, as a threat due to potential damage to their fishing gears and as having no economic value, as the carcasses cannot be sold. Depredation, or removal of fish captured in fishing gear by marine mammals, reduces the value of fishers' catch and may lead to higher risk of entanglement (Read, 2008). Despite some fishers' negative experiences of their interactions with cetaceans, it is unlikely that Matang fishers would intentionally kill the cetaceans. Most fishers in Matang who perceived an increase in cetacean abundance said that cetaceans were not purposely harmed in Matang. Most of the fishers were aware that it is illegal to kill cetaceans intentionally. Some of the fishers believed that intentionally killing cetaceans would bring bad luck, even if they did not appreciate the net depredation behaviour of the animals. This is similar to the beliefs of villagers in Laos and Cambodia who believe that killing Irrawaddy dolphins results in bad luck (Baird et al., 1994).

Section 27 (3) of the Malaysian Fisheries Act 1985 states that marine mammals found to be caught alive must be released immediately, whereas if dead when found, must be reported to a fisheries officer without any penalty imposed (Ashraf & Mahmud, 2018). However, the reporting of bycatch in Matang to fisheries officers appeared to be extremely low, as only 3% of the respondents said that they would report to the authorities if they had a bycatch, and none of the 19 bycatch cases listed in Table 3 were reported to the authorities. The majority of the dead entanglements in Matang were most likely discarded at sea, probably due to the fishers' fear of legal actions and to avoid bringing any trouble to themselves, similar to observations reported in Fertl & Leatherwood (1997). Bycatch or damaged gears would cost fishers more money and time to disentangle the animals, and to repair or replace the damaged gears (Zollett & Rosenberg, 2005). Fishers should be encouraged to report their bycatch with the assurance by relevant government officers that there will not be any negative consequences or lawful actions taken against them. It is imperative that conservation scientists should work closely with fishers and the local authorities to develop suitable bycatch mitigation measures is of great importance to increase its effectiveness.

Although Matang is internationally designated as an IUCN IMMA, the area is currently not afforded protection as a marine protected or managed area, as existing marine parks in Malaysia are mostly established to conserve islands with coral reefs. With the current fishing within zone A (equivalent to approximately 1.8 to 14.8 km from the shore) in the state of Perak that allows gillnets, driftnets and trammel nets to operate, coupled with the lack of specific mitigation measures to significantly reduce cetacean bycatch in Malaysia, these fishing gears continue to pose deadly entanglement risks to coastal delphinids in Matang and throughout Malaysia. As such, priority for cetacean conservation should be given to these vulnerable cetaceans, especially to the smaller number of inshore humpback dolphins that have high reliance on the estuaries of Matang, and which are frequently exposed to high bycatch risks.

Bycatch mitigation trials should be targeted on working with gillnet/driftnet/trammel net fishers who fish in areas with high bycatch risk particularly off Kuala Sangga Besar and Kuala Larut (Figure 3). During interview surveys, some gillnet fishers expressed interest in low-cost bycatch mitigation, as long as their catch would not be affected. Trials on using acoustic reflectors such as acrylic glass spheres to increase the acoustic reflectivity of gillnets, or the use of acoustic pingers may be explored to better understand the efficiency of these tools to reduce cetacean bycatch in the long run (Hamilton & Baker, 2019; Kratzer et al., 2020). It is also important to ensure that the fishers' catch are not greatly affected by the bycatch mitigation measures to facilitate a wider adoption of these mitigation measures by more fishers in Matang and across Malaysia.

CONCLUSION

In Matang, the small number of inshore resident humpback dolphins off Kuala Sangga Besar and Kuala Larut are most at risk from entanglements in gillnets, driftnets and trammel nets. Irrawaddy dolphins and finless porpoises in the coastal waters also face bycatch risks from gillnets/driftnets/trammel nets and trawl nets, respectively. Bycatch mitigation trials such as the use of low-cost acoustic reflectors or pingers can be trialed on these small cetaceans. Efforts to test the effectiveness of bycatch mitigation in gillnets should be focused on working with fishers who had previous entanglements or gear damaged by cetaceans, and on those who use gillnets with mesh sizes of 1.5 to 4 inches to target threadfins, ariid catfishes, eel-catfishes, mullets, seabasses, and pomfrets in the high bycatch risk areas. Collaboration with local authorities and fishers to explore effective bycatch mitigation measures that do not affect the fishers' target catches would also ensure better conservation success.

Data quality used in ByRA particularly on bycatch/stranding data (Table 5) can be improved through mapping habitat suitability using maximum entropy modelling, improving interview survey effort and establishment of an operational stranding network to retrieve dolphin carcasses in Matang. Necropsies conducted on the retrieved carcasses of stranded animals by qualified veterinarians to determine the causes of death would be helpful to reduce the uncertainty level. Nevertheless, ByRA is a useful tool to raise concerns and prioritize bycatch mitigation efforts, especially when direct bycatch observation are difficult to come by.

The number of cetacean bycatch by 11 respondents in the last calendar year at the time of interview surveys were up to 22 cetaceans, and should be treated as the minimum annual cetacean bycatch rate in Matang. The actual number of bycatch is likely to be higher than this number, as this number was not extrapolated according to the proportion of fishers that were not interviewed. Additionally, the number of bycatch cases were likely to be underreported by fishers and not very reliable, possibly also owing to biased responses and memory decay (e.g., Whitty, 2016). Nevertheless, results from interview surveys with fishers provided invaluable insights to incidences of cetacean bycatch and perception of fishers towards cetaceans in Matang, which are fundamental to the success of bycatch mitigation and other conservation initiatives that are urgently needed.

ACKNOWLEDGEMENTS

This research was supported by funding from the University of Malaya Research Programme Grant No. RP001F-13SUS, University of Malaya Postgraduate Research Fund No. PG040-2013B and the Ocean Park Conservation Foundation Hong Kong Grant (MM03-1314). We thank Ng Jol Ern, Sandra Teoh and volunteers for their assistance in the field; and our skippers for their cooperation during the boat-based surveys. We appreciate the effort and help provided to us by Ellen Hines and Gregg Verutes on the ByRA analysis. The authors are also grateful for the support from the Perak State Forestry Department and the Department of Fisheries Malaysia.

REFERENCES

Ariffin, R., & Nik Mohd Shah, N. M. (2013). *A Working Plan for The Matang Mangrove Forest Reserve, Perak: The First 10-year Period (2010–2019) of the Third Rotation (Sixth Revision).*

Ashraf, M., & Mahmud, A. R. (2018). *An appraisal of the Malaysian legal framework in conserving the marine endangered species*. *December 2019*.

Ashton, E. C. (1999). *Biodiversity and community ecology of mangrove plants : molluscs and crustaceans in two mangrove forests in Peninsular Malaysia in relation to local management practices*. (Doctoral dissertation). University of York, York, UK.

Baird, I. G., Mounsouphom, B., & Stacey, P. J. (1994). Preliminary surveyes of Irrawaddy dolphins (*Orcaella brevirostris*) in Lao PDR and Northeastern Cambodia. *Report of the International Whaling Commission*.

Brown, S. L., Reid, D., & Rogan, E. (2013). A risk-based approach to rapidly screen vulnerability of cetaceans to impacts from fisheries bycatch. *Biological Conservation*, *168*, 78–87. https://doi.org/10.1016/j.biocon.2013.09.019

Brownell, R. L., Reeves, R. R., Read, A. J., Smith, B. D., Thomas, P. O., Ralls, K., Amano, M., Berggren, P., Chit, A. M., Collins, T., Currey, R., Dolar, M. L. L., Genov, T., Hobbs, R. C., Kreb, D., Marsh, H., Zhigang, M., Perrin, W. F., Phay, S., … Wang, J. Y. (2019). Bycatch in gillnet fisheries threatens Critically Endangered small cetaceans and other aquatic megafauna. *Endangered Species Research*, *40*, 285–296. https://doi.org/10.3354/ESR00994

Chong, V. C. (2005). Fifteen years of fisheries research in Matang mangroves : what have we learnt? In S. M. Ismail, A. Muda, R. Ujang, K. A. Budin, K. L. Lim, & S. Rosli (Eds.), *Sustainable Management of Matang Mangroves: 100 Years and Beyond, 4th Forest biodiversity Series* (pp. 411–429). Forestry Department Peninsular Malaysia.

Chong, V. C., Sasekumar, A., & Lim, K. H. (1994). Distribution and abundance of prawns in a Malaysian mangrove system. *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources. Chulalongkorn University), Bangkok, Vol. 2, Research Papers*, 437–445.

Chong, V. C., Teoh, H. W., Ooi, A. L., Jamizan, A. R., & Tanaka, K. (2012). Ingression and feeding habits of fish in Matang coastal mudflats, Malaysia. In *JIRCAS Working Report No. 75* (pp. 15–24). Japan International Research Center for Agricultural Sciences. http://www.jircas.affrc.go.jp/

Department of Fisheries Malaysia. (2015). *National Plan of Action for the Management of Fishing Capacity in Malaysia (Plan 2)*. Department of Fisheries Malaysia. http://www.dof.gov.my/dof2/resources/user_1/UploadFile/Penerbitan/Senarai Penerbitan/NPOA.pdf

Department of Fisheries Malaysia. (2016). *Annual Fisheries Statistics 2016*. https://www.dof.gov.my/dof2/resources/user_29/Documents/Perangkaan Perikanan/2016/Landing1.pdf

Fertl, D., & Leatherwood, S. (1997). Cetacean interactions with trawls: a preliminary review. *Journal of Northwest Atlantic Fishery Science*, *22*, 219–248.

Hamilton, S., & Baker, G. B. (2019). Technical mitigation to reduce marine mammal bycatch and entanglement in commercial fishing gear: lessons learnt and future directions. *Reviews in Fish Biology and Fisheries*, *29*(2), 223–247. https://doi.org/10.1007/s11160-019-09550-6

Hanamura, Y., Tanaka, K., Man, A., & Faizul Mohd Kassim. (2012). Ecological characteristics of hyperbenthic crustaceans in mangrove estuaries on the northwest coast of Peninsular Malaysia: An overview. *JIRCAS Working Report*, *75*, 25–34.

Hayase, S., & Muhd Fadzil, H. (1999). Fish distribution and abundance in Matang and Merbok mangrove waters, west coast of Peninsular Malaysia: preliminary results for 1996-1997. In K. Katsuhiro & P. S. Choo (Eds.), *Proceedings of the Fourth JIRCAS Seminar on Productivity and Sustainable Utilisation of Brackish Water Mangrove Ecosystems.* (pp. 50–91). Japan International Research Centre for Agricultural Sciences (JIRCAS).

Hines, E. M., Ponnampalam, L. S., Fairul Izmal, J. H., Whitty, T. S., Jackson-Ricketts, J., Kuit, S. H., & Acebes, J.-M. (2015a). Report of the Third Southeast Asian Marine Mammal Symposium (SEAMAM III). *CMS Technical Series Publication*, *32*, 643. https://doi.org/10.1017/CBO9781107415324.004

Hines, E. M., Strindberg, S., Junchumpoo, C., Ponnampalam, L. S., Ilangakoon, A. D., Jackson-Ricketts, J., & Monanunsap, S. (2015b). Line transect estimates of Irrawaddy dolphin abundance along the eastern Gulf Coast of Thailand. *Frontiers in Marine Science*, *2*(September), 1–10. https://doi.org/10.3389/fmars.2015.00063

Hines, E., Ponnampalam, L., Junchumpoo, C., Peter, C., Vu, L., Huynh, T., Caillat, M., Johnson, A., Minton, G., Lewison, R., & Verutes, G. M. (2020). Getting to the bottom of bycatch: a GIS-based toolbox to assess the risk of marine mammal bycatch. *Endangered Species Research*, *42*, 37–57. https://doi.org/10.3354/esr01037

Jefferson, T. A., Leatherwood, S., & Webber, M. A. (1993). Marine Mammals of the World. In *FAO Species Identification Guide* (Vol. 13, Issue 3). ftp://ftp.fao.org/docrep/fao/009/t0725e/t0725e12.pdf

Jefferson, T. A., Smith, B. D., Braulik, G. T., & Perrin, W. (2017). Sousa chinensis. *The IUCN Red List of Threatened Species 2017: e.T82031425A50372332*. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T82031425A50372332.en

Khalid, L., Pilcher, N., Phu, J., & Kooi Chee, H. (2021). *Turtle Excluder Device as a sustainable fishing practice in Malaysia*. https://www.cms.int/iosea-turtles/en/news/turtle-excluder-device-sustainable-fishing-practice-malaysia

Klein, S. C. (2017). Impacts of Hong Kong Trawling Ban on Chinese White Dolphins (Sousa chinensis). In *Fishing Regime Change Impact on Marine Mammals*.

Komoroske, L. M., & Lewison, R. L. (2015). Addressing fisheries bycatch in a changing world. *Frontiers in Marine Science*, *2*(October), 1–11. https://doi.org/10.3389/fmars.2015.00083

Kratzer, I. M. F., Schäfer, I., Stoltenberg, A., Chladek, J. C., Kindt-Larsen, L., Larsen, F., & Stepputtis, D. (2020). Determination of Optimal Acoustic Passive Reflectors to Reduce Bycatch of Odontocetes in Gillnets. *Frontiers in Marine Science*, *7*(July), 1–18. https://doi.org/10.3389/fmars.2020.00539

Kreb, D., Lhota, S., Porter, L., Redman, A., Susanti, I., & Lazecky, M. (2020). Long-Term Population and Distribution Dynamics of an Endangered Irrawaddy Dolphin Population in Balikpapan Bay, Indonesia in Response to Coastal Development. *Frontiers in Marine Science*, *7*(September). https://doi.org/10.3389/fmars.2020.533197

Kuit, S. H., Ponnampalam, L. S., Ng, J. E., Chong, V. C., & Then, A. Y. H. (2019a). Distribution and habitat characteristics of three sympatric cetacean species in the coastal waters of Matang, Perak, Peninsular Malaysia. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(10), 1681–1696. https://doi.org/10.1002/aqc.3121

Kuit, S. H., Ponnampalam, L. S., Ng, J. E., Fairul Izmal, J. H., & Chong, V. C. (2015). Selection factors of Sagor catfish (*Hexanematichthys sagor*) as prey by Indo-Pacific humpback dolphins (*Sousa chinensis*) in the estuaries of Matang, Perak, Malaysia. In *Poster presentation at the Society of Marine Mammalogy 21st Biennial Conference, San Francisco, CA, USA. December, 2015.*

Kuit, S. H., Then, A. Y.-H., Ng, J. E., Teoh, Z. Y., & Ponnampalam, L. S. (2019b). Ranging patterns of Indo- Pacific humpback dolphins (*Sousa chinensis*) in the Matang Important Marine Mammal Area in Perak, Peninsular Malaysia. In *Poster presentation at the World Marine Mammal Conference, Barcelona, Spain. December, 2019.*

Lewison, R. L., Crowder, L. B., Read, A. J., & Freeman, S. A. (2004). Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology and Evolution*, *19*(11), 598–604. https://doi.org/10.1016/j.tree.2004.09.004

Low, C. B., Chong, Vi. C., Hayase, S., & Lim, L. H. S. (1999). Prawn production of Matang and Dinding River mangroves: Species distribution and seasonal recruitment. In K. Kiso & P. S. Choo (Eds.), *Production and Sustainable Utilization of Brackish Water Mangrove Ecosystems, Proceedings of the 4th Seminar of Results of 1997/98 Research Projects* (pp. 89–101). Japan International Research Centre for Agricultural Sciences and Ministry of Aqriculture Malaysia, Penang. http://repository.um.edu.my/63169/

Minton, G., Smith, B. D., Braulik, G. T., Kreb, D., Sutaria, D., & Reeves, R. (2017). Orcaella brevirostris. *The IUCN Red List of Threatened Species 2017: e.T15419A50367860.* http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15419A50367860.en.

Moore, J. E., Cox, T. M., Lewison, R. L., Read, A. J., Bjorkland, R., McDonald, S. L., Crowder, L. B., Aruna, E., Ayissi, I., Espeut, P., Joynson-Hicks, C., Pilcher, N., Poonian, C. N. S., Solarin, B., & Kiszka, J. (2010). An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation*, *143*(3), 795–805. https://doi.org/10.1016/j.biocon.2009.12.023

Nelms, S., Alfaro-Shigueto, J., Arnould, J., Avila, I., Bengtson Nash, S., Campbell, E., Carter, M., Collins, T., Currey, R., Domit, C., Franco-Trecu, V., Fuentes, M., Gilman, E., Harcourt, R., Hines, E., Rus Hoelzel, A., Hooker, S., Johnston, D., Kelkar, N., … Godley, B. (2021). Marine mammal conservation: over the horizon. *Endangered Species Research*, *44*, 291–325. https://doi.org/10.3354/esr01115

Parra, G. J., & Jefferson, T. A. (2018). Humpback Dolphins. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (pp. 483–489). Elsevier. https://doi.org/10.1016/B978-0-12-804327-1.00153-9

Pilcher, N. (2016). Turtle excluder devices in Malaysia-progress, steadily but surely. *Indian Ocean Turtle Newsletter No.22*, 20–23.

Pilcher, N. J., Adulyanukosol, K., Das, H., Davis, P., Hines, E., Kwan, D., Marsh, H., Ponnampalam, L. S., & Reynolds, J. (2017). A low-cost solution for documenting distribution and abundance of endangered marine fauna and impacts from fisheries. *PLoS ONE*, 1–15. https://doi.org/10.1371/journal.pone.0190021

Pilcher, N. J., & Kwan, D. (2012). *Dugong questionnaire survey project manual*. *September*, 44.

Read, A. J. (2008). The looming crisis: interactions between marine mammals and fisheries. *Journal of Mammalogy*, *89*(3), 541–548. https://doi.org/10.1644/07-MAMM-S-315R1.1

Reeves, R., McClellan, K., & Werner, T. (2013). Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. *Endangered Species Research*, *20*(1), 71–97. https://doi.org/10.3354/esr00481

Sasekumar, A., Chong, V. C., & Harinder, R. S. (1994). The physical and chemical characteristics of Matang Mangrove waters. *Proceedings of the Third ASEAN-Australia*

Symposium on Living Coastal Resources, Vol. 2: Research Papers, Chulalongkorn University, Bangkok, Thailand, 446–453.
Slooten, E., Dawson, S. M., & Davis, R. W. (2021). Delays in Protecting a Small Endangered Cetacean : Lessons Learned for Science and Management. *Frontiers in Marine Science, 8*(March), 1–13. https://doi.org/10.3389/fmars.2021.606547
Soulsbury, C., Iossa, G., & Harris, S. (2008). The Animal Welfare Implications of Cetacean Deaths in Fisheries. *Whale and Dolphin Conservation Society*, 1–54. http://au.whales.org/sites/default/files/work/wdcs_bycatchreport_2008_full.pdf
Stacey, P. J., & Leatherwood, S. (1997). The Irrawaddy dolphin, *Orcaella brevirostris*: a summary of current knowledge and recommendations for conservation action. *Asian Marine Biology*, *14*, 195–214.
Tanaka, K., Hanamura, Y., Chong, V. C., Watanabe, S., Man, A., Kassim, F. M., Kodama, M., & Ichikawa, T. (2011). Stable isotope analysis reveals ontogenetic migration and the importance of a large mangrove estuary as a feeding ground for juvenile John's snapper *Lutjanus johnii*. *Fisheries Science*, *77*(5), 809–816. https://doi.org/10.1007/s12562-011-0396-x
Then, A. Y. H. (2008). *The structure and trophodynamics of the fish community in estuaries of Matang Mangrove Forest Reserve, Peninsular Malaysia*. (Master's thesis). University of Malaya, Kuala Lumpur, Malaysia.
Verutes, G. M., Johnson, A. F., Caillat, M., Ponnampalam, L. S., Peter, C., Vu, L., Junchompoo, C., Lewison, R. L., Hines, E. M., Andrew F., Johnson Marjolaine, C., Ponnampalam, L. S., Peter, C., Vu, L., Junchompoo, C., Lewison, R. L., Hines, E. M., Johnson, A. F., Caillat, M., Ponnampalam, L. S., … Andrew F., Johnson Marjolaine, C. (2020). Using GIS and stakeholder involvement to innovate marine mammal bycatch risk assessment in data-limited fisheries. *Plos One*, *15*(May), 1–25. https://doi.org/10.1371/journal.pone.0237835
Wang, J. Y., & Reeves, R. (2017). Neophocaena phocaenoides. *The IUCN Red List of Threatened Species 2017: e.T198920A50386795*. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T198920A50386795.en
Whitty, T. S. (2014). *Conservation-scapes: An interdisciplinary approach to assessing cetacean bycatch in small-scale fisheries* [(Doctoral dissertation). University of California, San Diego]. https://escholarship.org/uc/item/2619j4z8
Whitty, T. S. (2016). Multi-methods approach to characterizing the magnitude, impact, and spatial risk of Irrawaddy dolphin (*Orcaella brevirostris*) bycatch in small-scale fisheries in Malampaya Sound, Philippines. *Marine Mammal Science*, *32*(3), 1022–1043. https://doi.org/10.1111/mms.12322
Whitty, T. S., Davis, P., & Poonian, C. (2010). Rapid assessment of marine megafauna capture, fishing effort, and socioeconomic and cultural drivers of artisanal fisheries in Northern Madagascar. *Proceedings of the World Small Scale Fisheries Congress (Bangkok)*.
Zollett, E. A., & Rosenberg, A. A. (2005). *A Review of Cetacean Bycatch in Trawl Fisheries. Literature Review: prepared for the Northeast Fisheries Science Center, New Hampshire, U.S.A.*